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OVERVIEW AND CURRENT STATUS OF THE EXPERIMENTAL CAPACITY OF THE LECI HOTLAB FACILITY

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1. Context
2. The LECI facility
3. Current experimental capabilities
4. On-going projects
5. Conclusion

Missions of the LECl facility

- To characterize **non-fissile irradiated materials** = Metallurgical, mechanical, physical-chemical characterizations in order :
 - to determine their behavior in normal, accidental or storage conditions
 - to predict their in-service lifetime (+ models)

- Materials from surveillance programs (NPP) or from irradiations in Material Testing Reactors
 - Generation 2&3 reactors:
 - Reactor pressurized vessel (life extension) → embrittlement, mechanical properties
 - Internals (304, 316 steels) → swelling, creep, stress corrosion cracking
 - Zirconium alloys for fuel pin cladding and assembly
 - Generation IV reactors (sodium or gas cooled FBR) :
 - Steels, ODS, ceramics, refractory materials, graphite (fuel pin cladding and assembly)
 - MTR
 - Aluminum alloys (vessel and cladding)

1. CONTEXTE

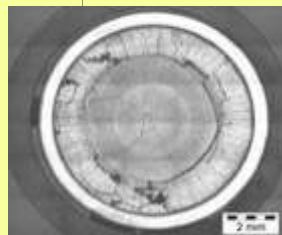
Operate 45 hotcells



Evacuation of used fuels



Respond to R&D programs



Cell cleanings, Installation of new equipment



1. Context

2. The LECI facility

3. Current experimental capabilities

4. On-going projects

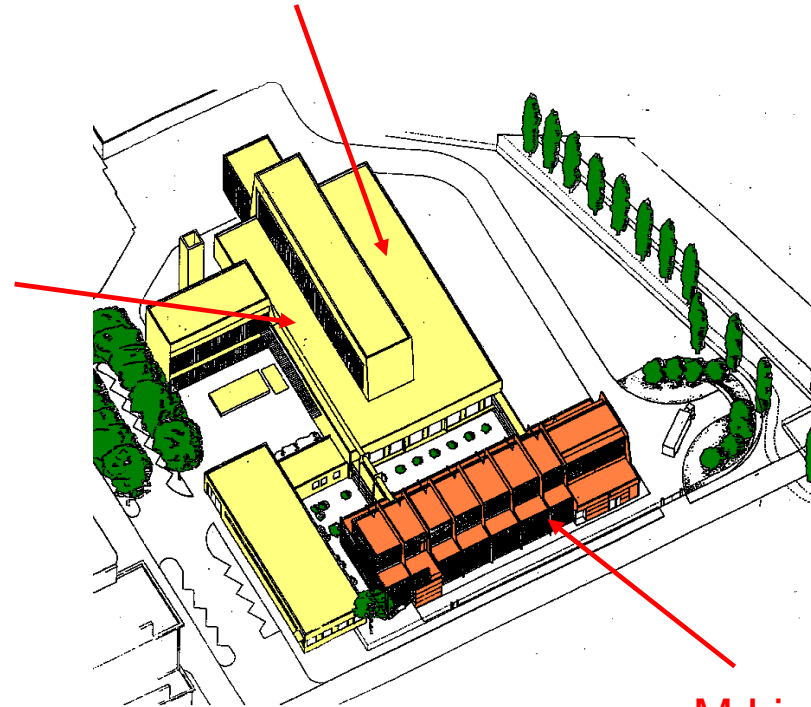
5. Conclusion

2. THE LECI FACILITY



K Line (Active in 1959)

I Line (1970)

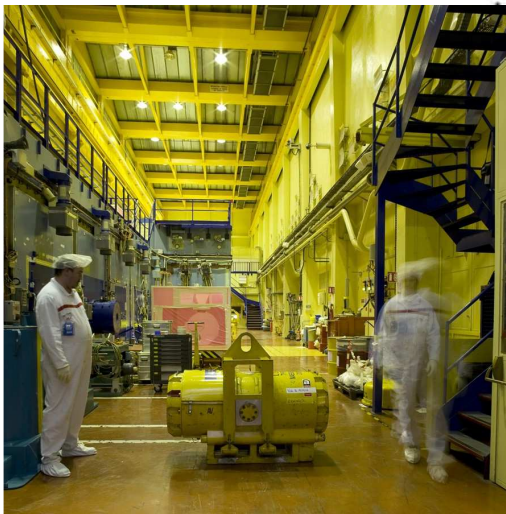
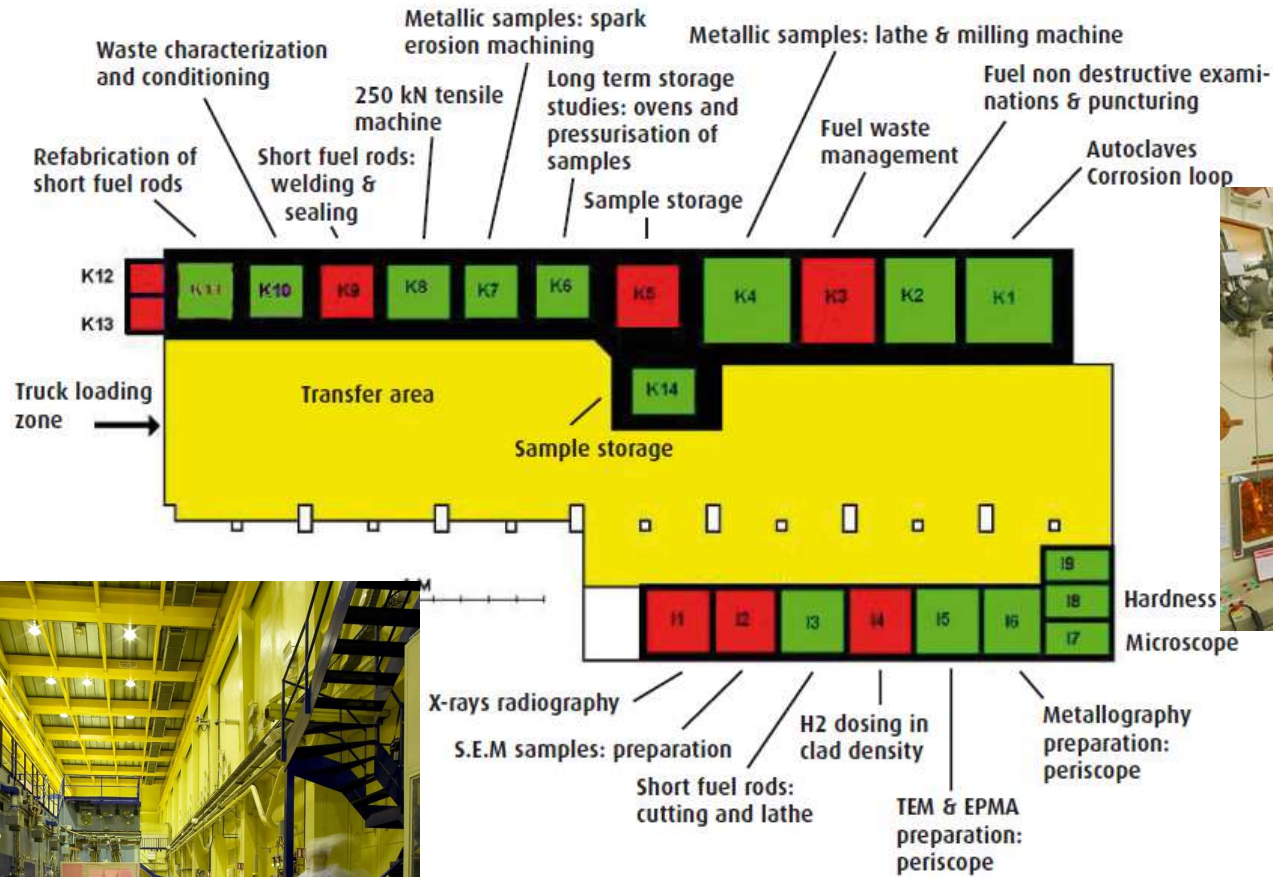


M Line (2005)



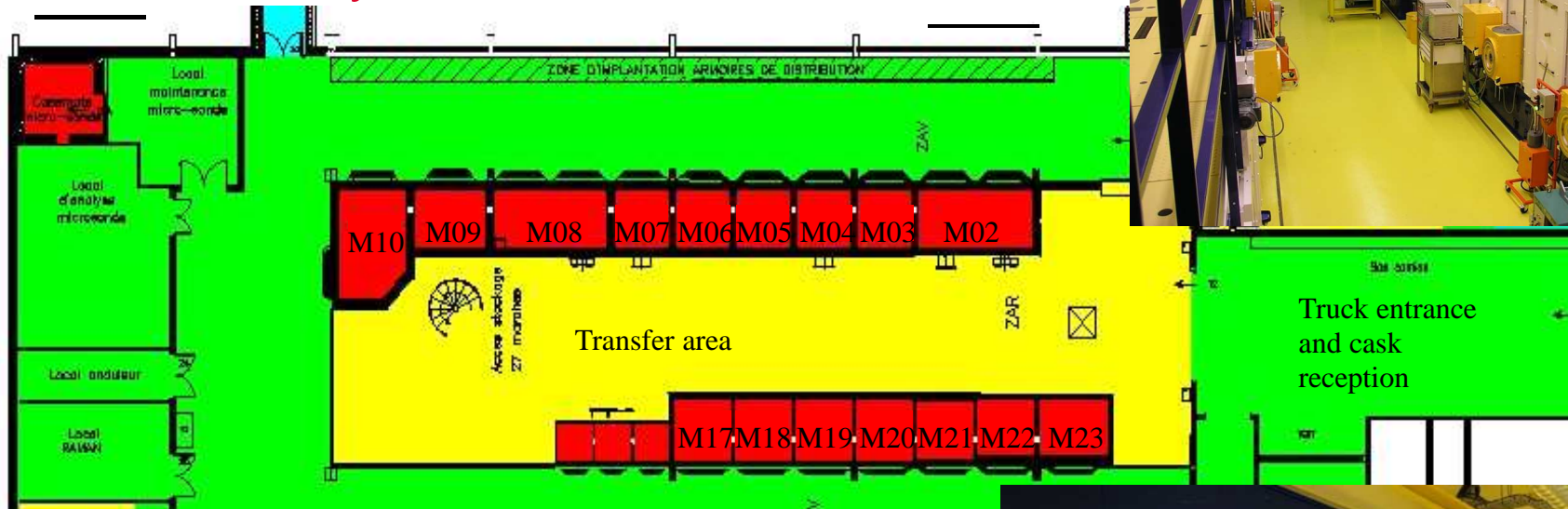
2. THE LECI FACILITY

Layout of the I & K Lines



2. THE LECI FACILITY

Layout of the M Line



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Testing capacity summary

- Metallography and optical microscopy
- SEM, TEM, and EPMA
- Micro-hardness
- Density measurements
- Thermoelectric power
- H₂ measurements
- Eddy currents
- Metrology (non-contact measurements)

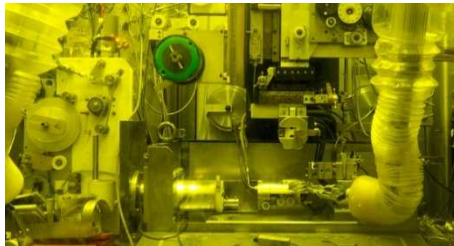


- Tensile testing (10, 25 and 100 kN, -170 to 1800°C, dynamic capacities (0.5 m/s), fast heating (induction and Joule effect)
- Fracture toughness (100 and 250 kN, -170 to 1000°C)
- 50 J and 350 J Charpy testing
- Burst machine coupled to tensile testing machine
- Axial creep tests
- Internal pressure creep tests
- Burst and creep under iodine (CSCI)
- 2 Autoclaves (360°C, 220 bar, 1 coupled to slow tensile testing) in hot cell
- Machining (conventional & wire spark erosion machining)
- Welding (TIG and Laser)

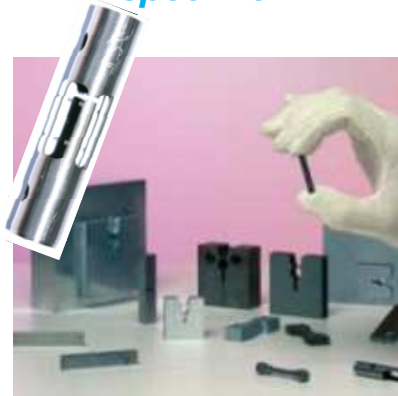
CURRENT EXPERIMENTAL CAPABILITIES

Machining of samples

Wire spark erosion machining

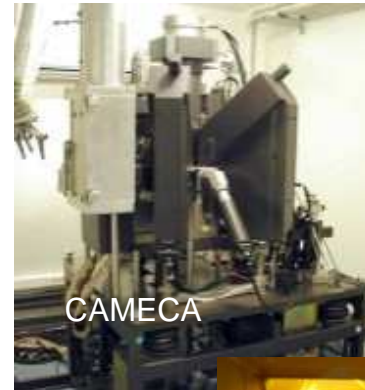


Machined specimen

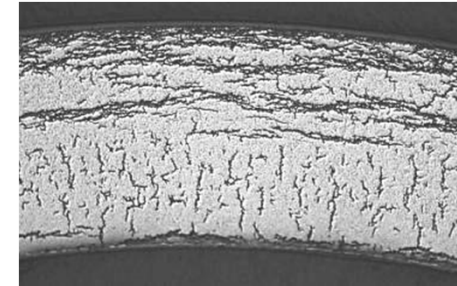


Metallurgical and physico-chemical characterizations

EPMA



Metallography



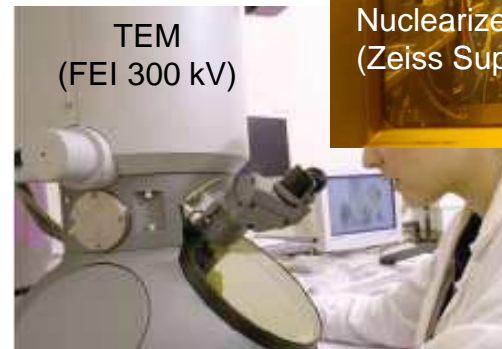
Corrosion (tests & modeling) of irradiated materials

Corrosion loop (2 Autoclaves)

(360°C, 220 bar, 1 coupled to slow tensile testing)



TEM
(FEI 300 kV)



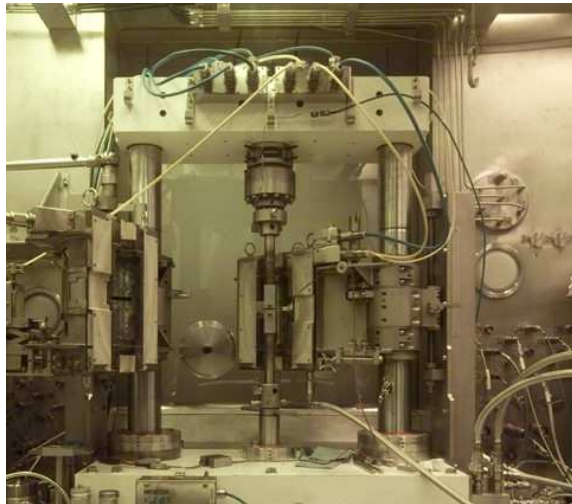
Nuclearized SEM
(Zeiss Supra 55)



CURRENT EXPERIMENTAL CAPABILITIES

Mechanical characterization of irradiated materials (examples)

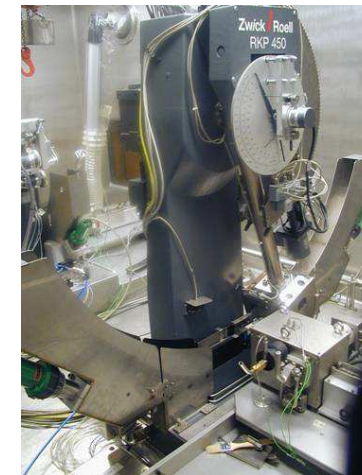
Toughness Testing Servo-Hydraulic Machine (100 kN)



CT 20 specimen after test



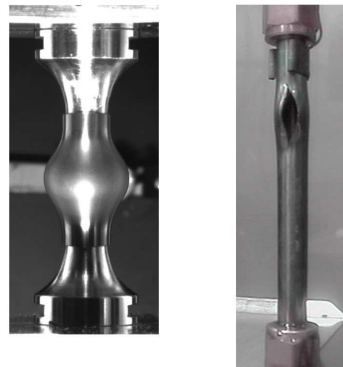
350 J Charpy Impact Testing



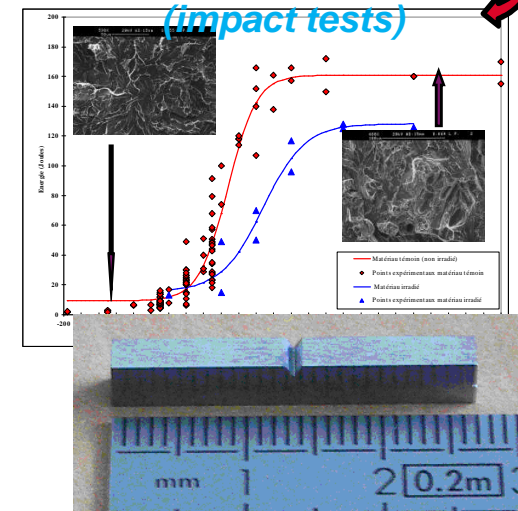
Biaxial Testing of Cladding (Internal Pressure + Axial Load)



biaxial testing / expansion due to compression, inner pressure coupled with axial tensile testing



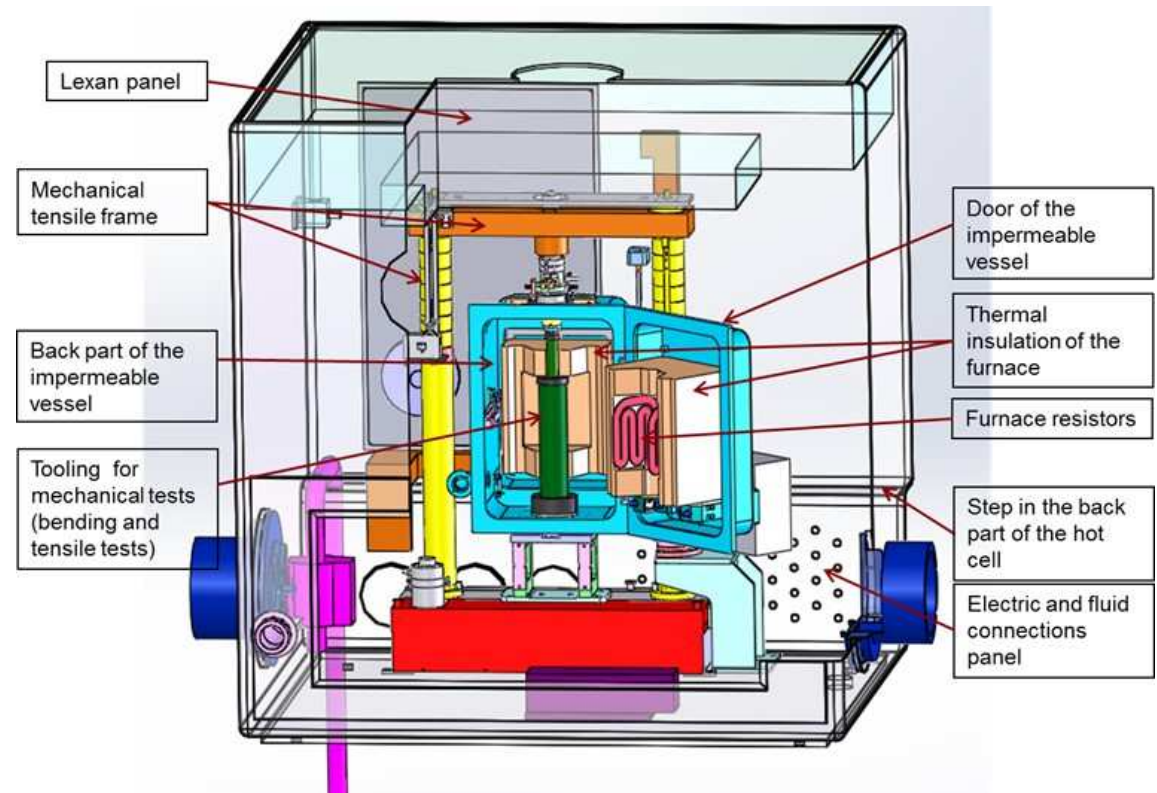
Ductile-Brittle transition (impact tests)



High Temperature (up to 1800°C) Tensile Machine

■ To study the behavior of materials dedicated to the GEN IV reactors (sodium/gas cooled fast reactors), in nominal, incidental and accidental conditions

- stainless steels (ferritic-martensitic ODS steels, austenitic, advanced austenitic)
- other advanced metallic materials
- ceramic composites, such as SiC/SiC



High Temperature (up to 1800°C) Tensile Machine

- Mechanical tensile machine - INSTRON
 - Two alternatively used load cells (10 kN and 1 kN)
 - A 30 kN capacity with a 650 mm wide testing space
 - Maximal travel of the cross rail of about 1135 mm
 - Adjustable speed of the cross rail from 0.001 to 500 mm/min
 - Retraction speed of the cross rail: 600mm/min with controlled deceleration for precise positioning

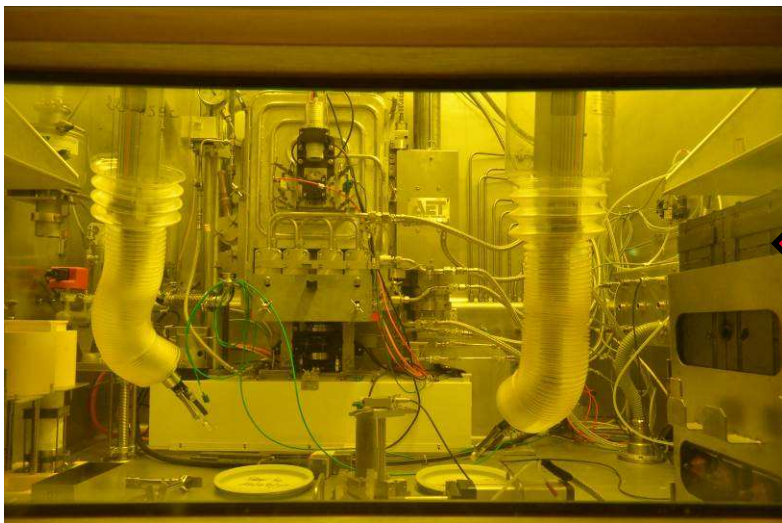
- Furnace with controlled atmosphere – AET
 - Metallic furnace (molybdenum) : T<1200°C (metallic materials), heating rate : 5°C/min
 - Graphite furnace: T<1800°C (ceramics, graphite), heating rate : 30°C/min
 - Controlled atmosphere (Helium, Argon, vacuum) → to avoid oxidation at the very high testing temperatures



CURRENT EXPERIMENTAL CAPABILITIES

High Temperature (up to 1800°C) Tensile Machine

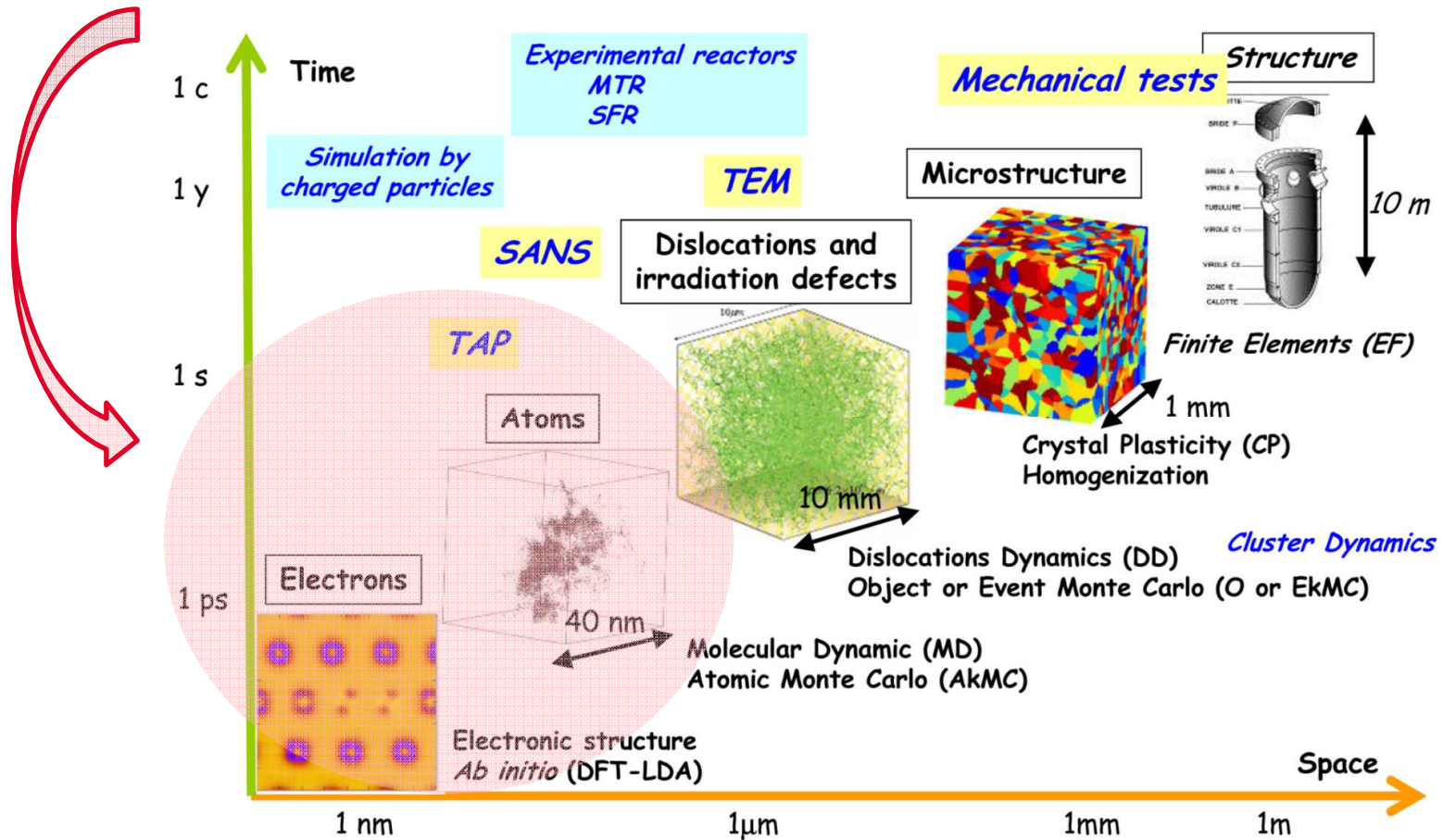
- Recently installed in hot cell (M line – Cell M18)
- Commissioning tests in progress



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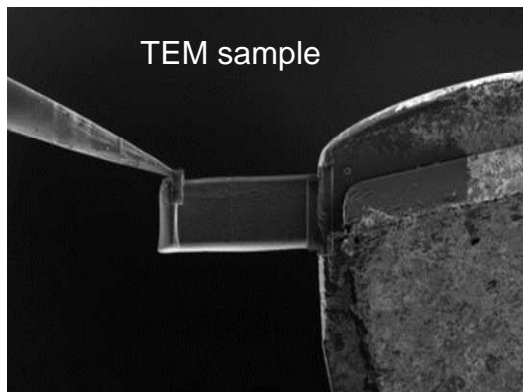
5. ON-GOING PROJECTS

An experimental Platform for the Analysis of Irradiated Material at the Nano-metric Scale



An experimental Platform for the Analysis of Irradiated Material at the Nano-metric Scale

- A SEM with Focused Ion Beam used to :
 - Locate precisely TEM and TAP samples (grain boundaries, end of a crack tip, interface,...)
 - Prepare lower activity TEM and TAP samples (and reduce hazardous liquid wastes)

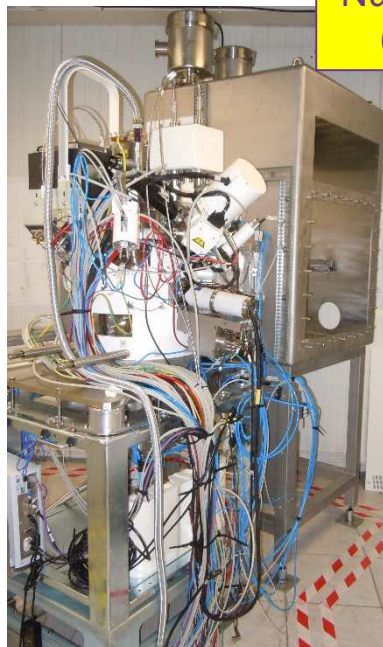


Non nuclearized FIB-SEM
(Zeiss Auriga 40)



An experimental Platform for the Analysis of Irradiated Material at the Nano-metric Scale

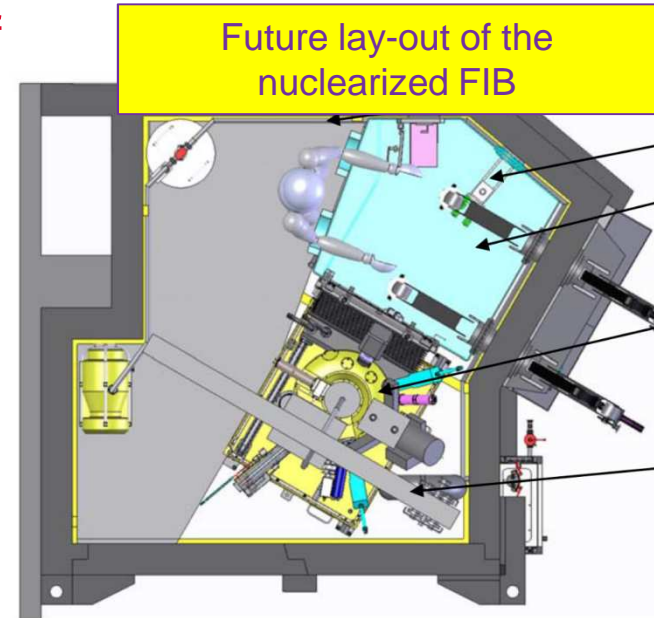
- The nuclearized FIB-SEM is in service outside hot cell
- The installation in hot conditions is foreseen mid 2018 (construction of the dedicated shielding in progress ~100 t)



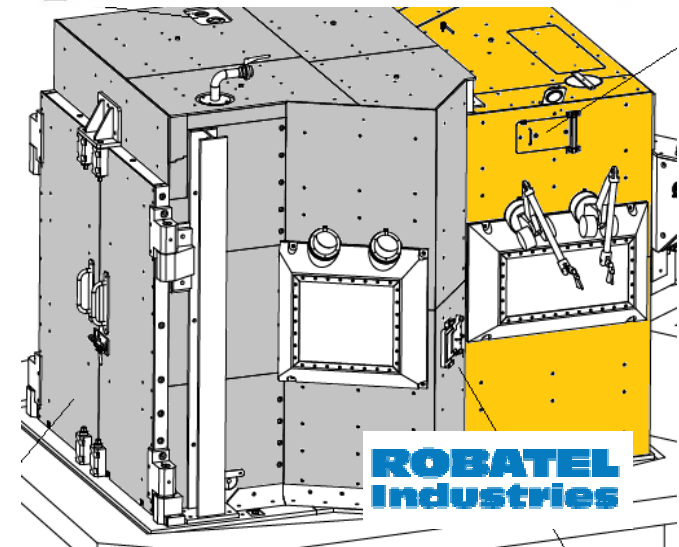
Nuclearized FIB-SEM
(Zeiss Auriga 40)



Défi-Systèmes
ZEISS



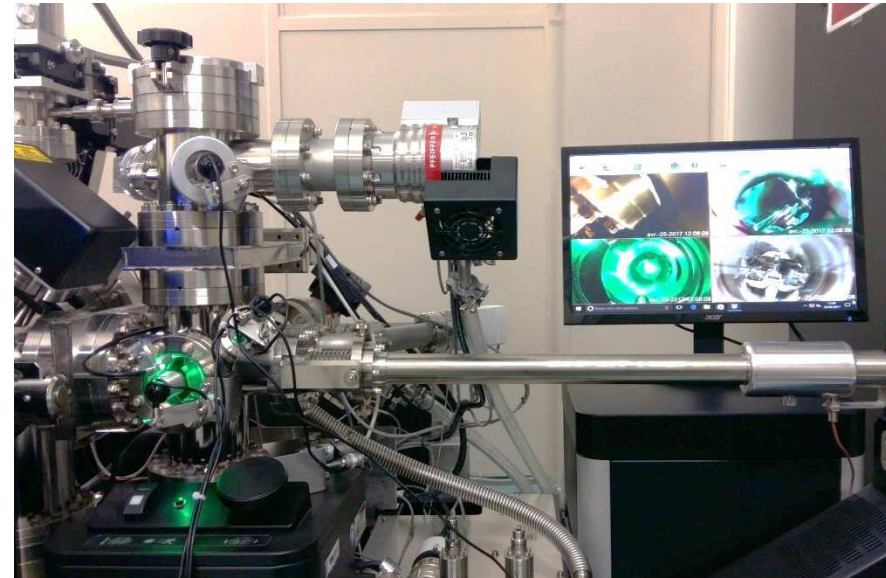
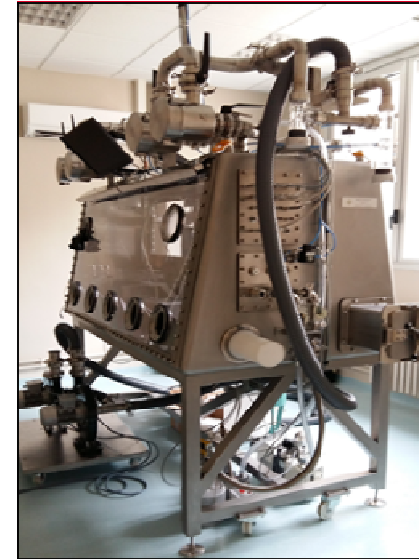
Future lay-out of the nuclearized FIB



ROBATEL
Industries

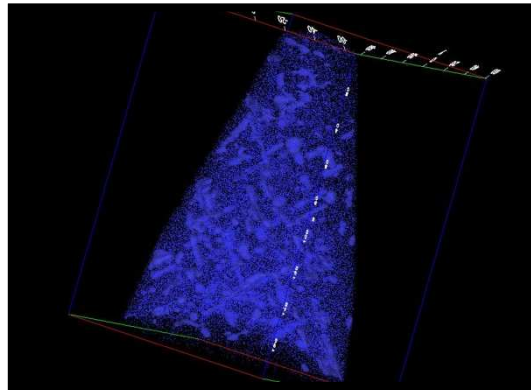
An experimental Platform for the Analysis of Irradiated Material at the Nano-metric Scale

- Installation of a TAP achieved in 2013
 - Operating on **ion irradiated material**
 - Used on Al alloys, ODS steels, Fe-Cr model alloys, Zr alloys and Zr oxides
- Installation of a glovebox achieved early 2017
- Operation on neutron irradiated materials is due mid 2018

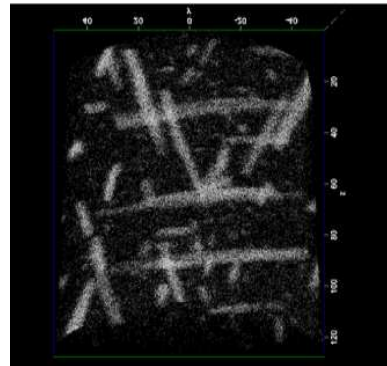


An experimental Platform for the Analysis of Irradiated Material at the Nano-metric Scale

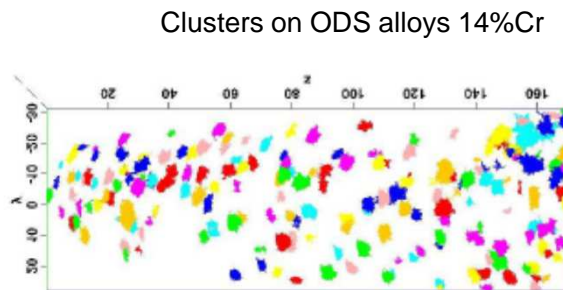
Some examples of research on the TAP and Hot SEM-FIB



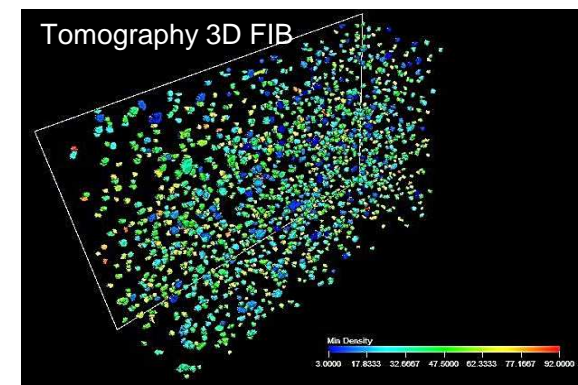
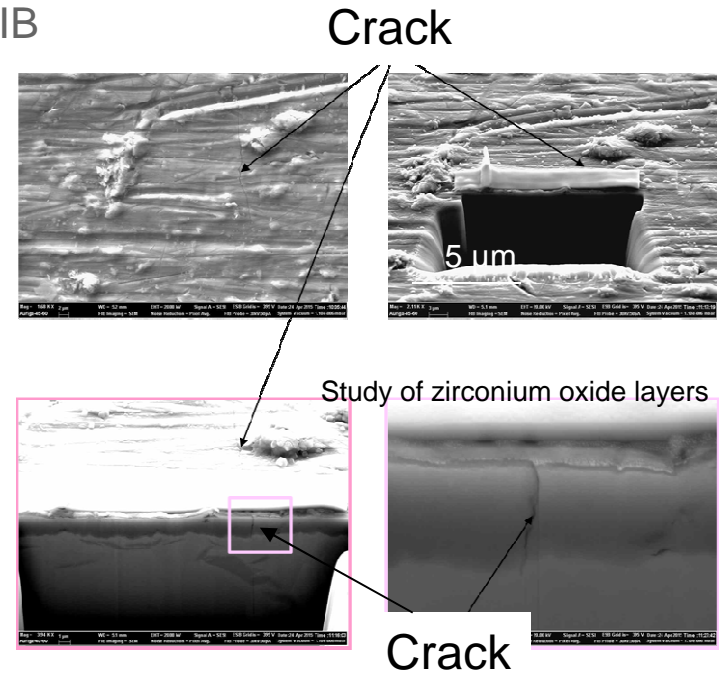
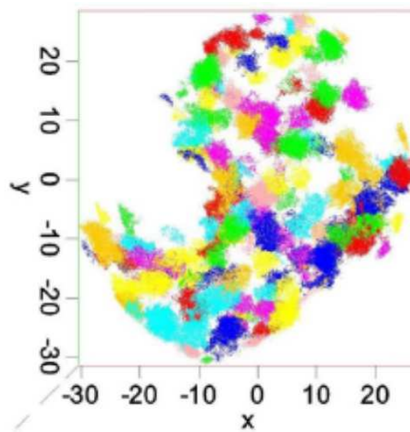
Ion-irradiated Fe-10Cr alloys : Cr segregation on dislocation loops



β'' precipitates on 6061-T6 aluminum



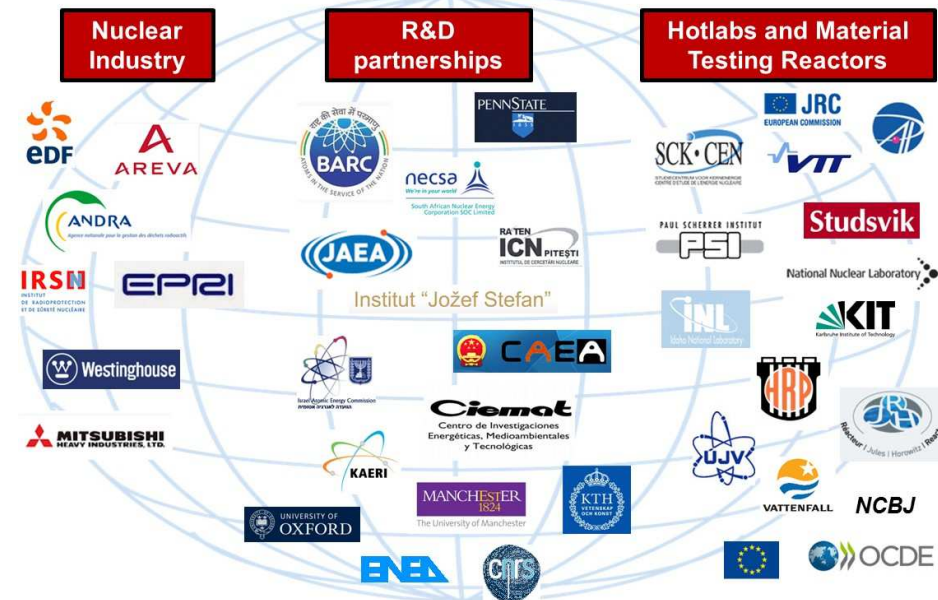
Clusters on ODS alloys 14%Cr



Nota : This work profited from a French government grant managed by the National Agency of Research under the program "Investments for the future" (ref. ANR-11-EQPX-0020)

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- LECI → A world-class, comprehensive and modern hot laboratory devoted to the characterization of irradiated non-fissile materials
- The last safety review in 2015 stated the operability of the LECI for the next ten years
- LECI keeps on upgrading its experimental capacities, such as
 - the implementation of a high Temperature Tensile Machine in hot cell
 - the commissioning of a TAP & a SEM-FIB in hot conditions
- LECI is open to national and international clients through direct contracts or international scientific collaboration.





Thank you
for your attention !

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